



COAMPS-TC: Recent Progress and Future Plans

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Monterey, CA**



COAMPS-TC

Outline

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- Background
- COAMPS-TC Description
- Real-Time COAMPS-TC Runs during T-PARC/TCS08
 - **System configuration**
 - **Results**
 - **Prototype coupled model tests**
 - **Improvements following TCS08/T-PARC**
- Real-Time Sensitivity & Targeting during T-PARC
- Conclusions/Future Research



COAMPS-TC

Background

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- **COAMPS-TC: New version of COAMPS® developed for tropical cyclone track, intensity, and structure prediction:**
 - Improved TC analysis, microphysics, air-sea fluxes and boundary layer
- THORPEX Pacific Asian Regional Campaign (T-PARC) Tropical Cyclone Structure '08 (TCS08) Experiment
 - **Objectives:**
 - Observe TCs and environment from genesis to extratropical transition.
 - Targeted Observing: Additional observations in regions where they are most likely to improve forecasts.
- COAMPS-TC real-time forecasts for T-PARC/TCS08
 - Assess the skill of the COAMPS-TC predictions
 - Perform follow-on research to improve the prediction of the TC track, structure, and intensity



COAMPS-TC Overview

Complete System Under Development

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Atmospheric Analysis	Ocean Analysis
<ul style="list-style-type: none">•Complex Data Quality Control•Relocation of TC in background•NAVDAS 3DVAR: u, v, T, q, TC option•Initialization: Hydrostatic Constraint on Analysis Increments, and/or Digital Filter	<ul style="list-style-type: none">•Navy Coupled Ocean Data Assimilation (NCODA) System•2D OI: SST•3D MVOI: T, S, SSH, Sea Ice, Currents•Complex Data Quality Control•Initialization: Stability check
Atmospheric Model	Ocean Models
<ul style="list-style-type: none">•Numerics: Nonhydrostatic, Scheme C, Nested Grids, Sigma-z, Flexible Lateral BCs•Physics: PBL, Convection, Explicit Moist Physics, Radiation, Surface Layer•TC Tools: Moving nests, dissipative heating, spray parameterization, shallow convection	<ul style="list-style-type: none">•NRL Coastal Ocean Model (NCOM)•Numerics: Hydrostatic, Scheme C, Nested Grids, Hybrid Sigma/z•Physics: Mellor-Yamada 2.5•Wave Models (WWIII and SWAN)•Generalized Flux Coupler (ESMF)



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Configuration for T-PARC/TCS08

5

Atmospheric Analysis	Ocean Analysis
<ul style="list-style-type: none">• Complex Data Quality Control• Relocation of TC in background• NAVDAS 3DVAR: u, v, T, q, TC option• Initialization: Hydrostatic Constraint on Analysis Increments, and/or Digital Filter	<ul style="list-style-type: none">• Navy Coupled Ocean Data Assimilation (NCODA) System• 2D OI: SST• 3D MVOI: T, S, SSH, Sea Ice, Currents• Complex Data Quality Control• Initialization: Stability check
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Ocean Model was not used in TCS-08 runs



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Real-Time Modeling for T-PARC/TCS08

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Inputs

T-PARC/TCS08

Input

- T-PARC Invest
- Targeting Alert
- JWC Warning Message

Routine Observations

- Satellite
- Radiosondes
- Surface
- Commercial Aircraft

T-PARC/TCS08 Observations

- Drop/Driftsondes
- Satellite
- Aircraft
- AXBTs

Models

COAMPS-TC

- Track, Structure, Intensity
- 45/15/5 km nests
- Uncoupled

Invest COAMPS-TC

- Genesis
- 45/15/5 km
- 5 km relocated on demand

Adjoint COAMPS-TC

- Targeting Genesis
- First time ever
- Response function relocated each fcst

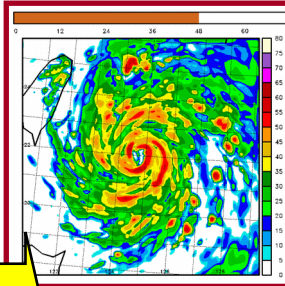
Computers

AFRL SGI Altix 4700

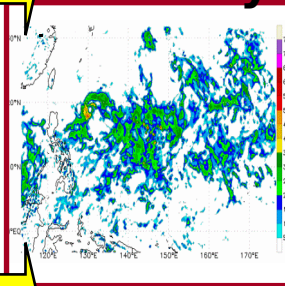
NAVO IBM P5

NRL LINUX Cluster

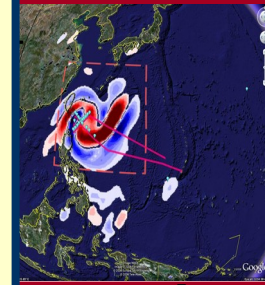
Products



Intensity



Genesis



Targeting

Field Campaign

Products

- Digital
- NRL www
- T-PARC catalog

Decision Making

- Forecast Discussions
- Mission Planning
- Adaptive nests, adjoint areas

Missions

- Real-time observations
- Evaluation
- Targeting



COAMPS-TC

Real-Time Modeling for T-PARC/TCS08

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**45/15/5 km grids set up
for WPAC (TCS-08) basin**

**45 km grid fixed for all
storms**

**Inner 2 grids move with
the TC**

**Automatically submitted
based on “ngt” file from
FNMOG (JTWC warning
message)**

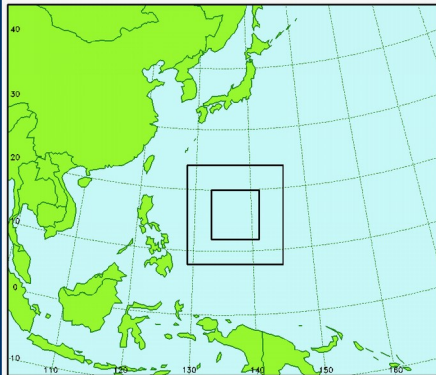
Sample contents of ngt file:

```
04 08092912      at 20080929  204508
172N 1093E 045 20 W -999 -999 -999 -999 055 055 055 055 2950 100 b
089N 1296E 030 21 W -999 -999 -999 -999 -999 -999 -999 -999 2750 180 b
272N 1221E 055 19 W 040 040 040 040 100 100 100 100 0150 080 b
371N 0476W 050 12 L 080 100 -999 -999 240 200 150 180 2850 070 b
```

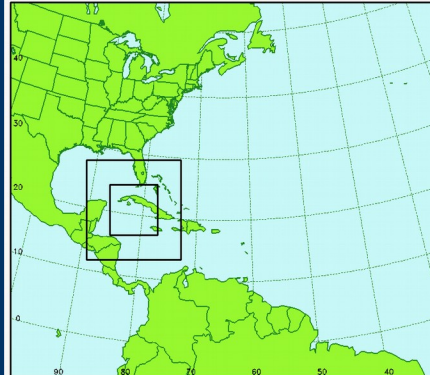
**45/15/5 km grids also set up for WATL, EPAC, and
CPAC basins**

**These forecasts were run using the same
configuration as the WPAC basin, except for the
grid location**

WPAC



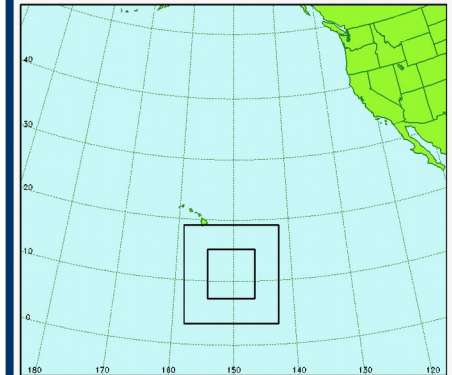
WATL



EPAC



CPAC





COAMPS-TC

Real-Time Modeling for T-PARC/TCS08

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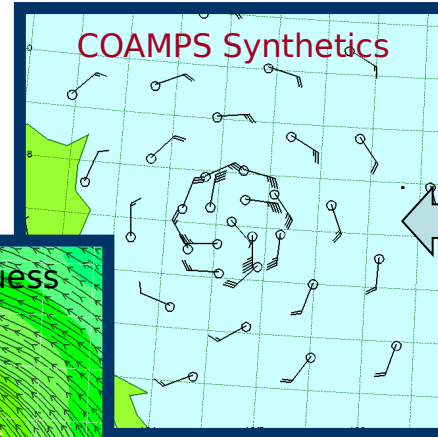
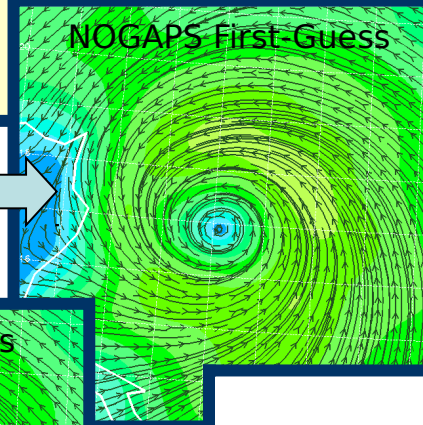
Typhoon Sinlaku (15W) (0000 UTC 9 August 2008)

• Synthetic Observations Built From:

- **Modified Rankine Vortex**
- **JTWC Warning Message w/Satellite Data**
- **NOGAPS T20/L15 truncated fields**

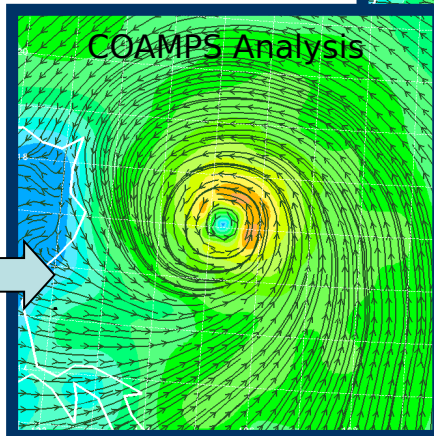
• **Blend Synthetics w/all other observations in 3DVAR**

NOGAPS first-guess fields - have their own TC structure



Synthetics to represent TC circulation

Improved TC representation with synthetics using 3DVAR



Issues/Comments

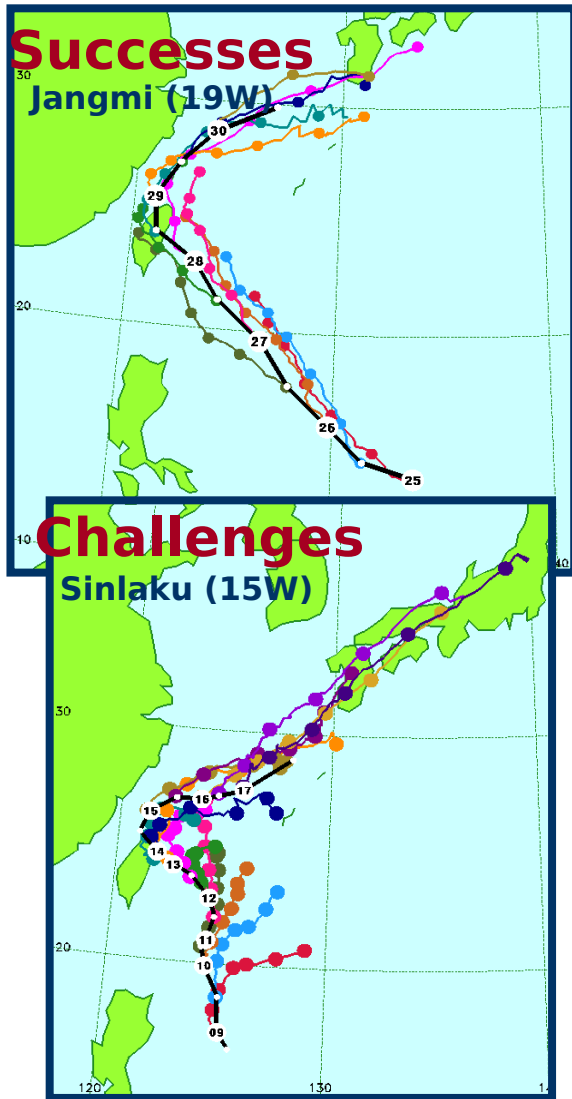
- **For warm-starts, TC circulation is relocated to warning position**
- **Some influence of NOGAPS TC circulation seen in COAMPS analysis fields (cold starts)**
- **3DVAR leads to small-scale “spokes” in horizontal wind distribution**
- **Imbalances apparent in the initial state**



COAMPS-TC

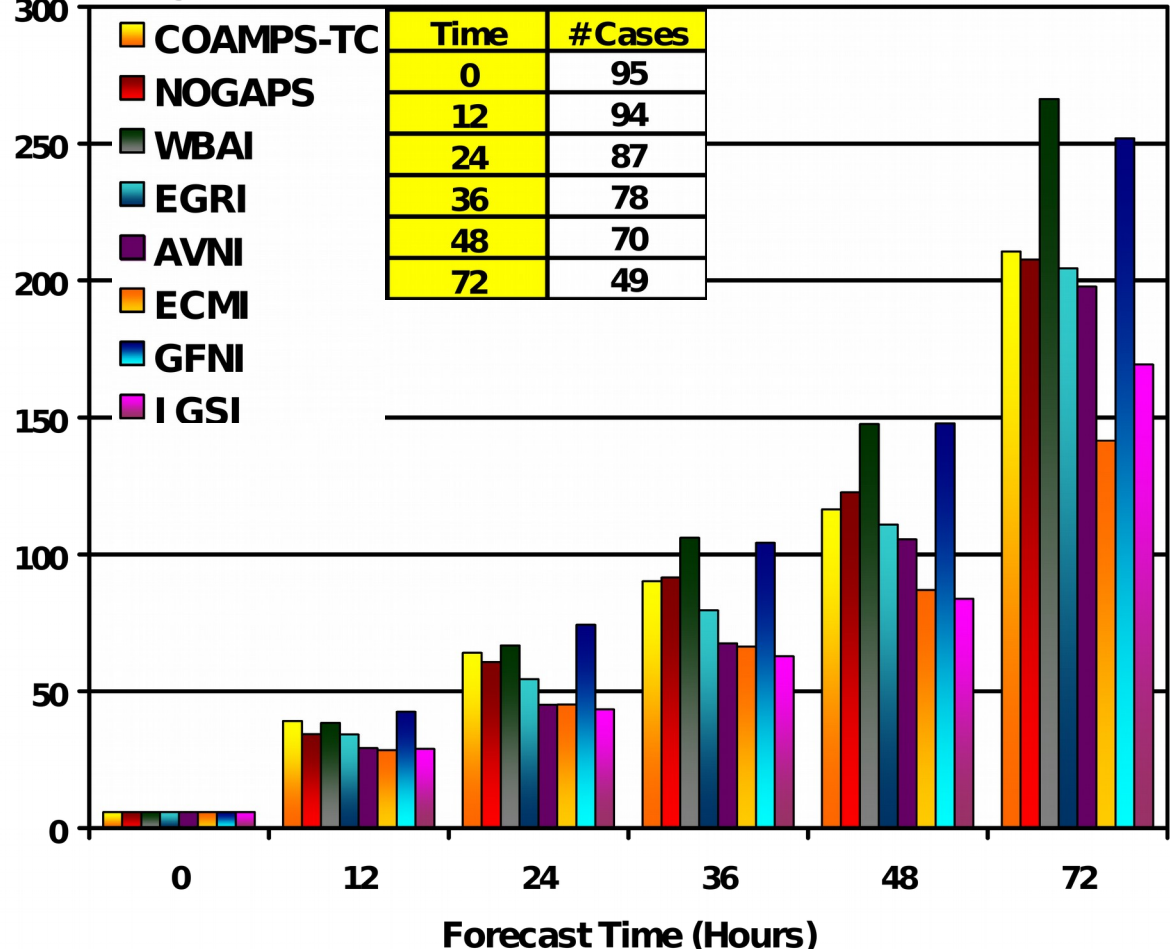
COAMPS-TC Track Forecasts for T-PARC/TCS08

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Black line: **Warning positions**
Colored lines: **COAMPS**

Homogeneous Sample Compared to all Models for TC



COAMPS-TC slightly underperforms in TC track early in the forecast, but does well at later forecast times outperforming GFNI and competitive with other models.

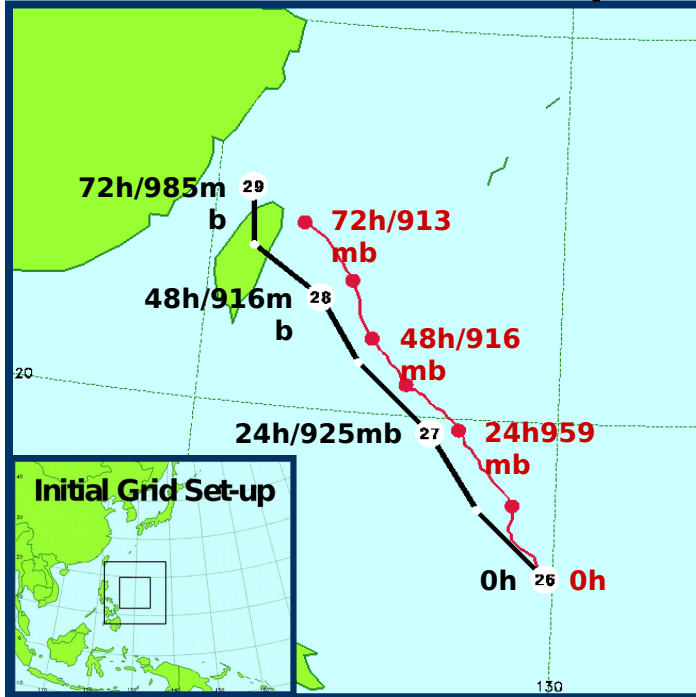


COAMPS-TC

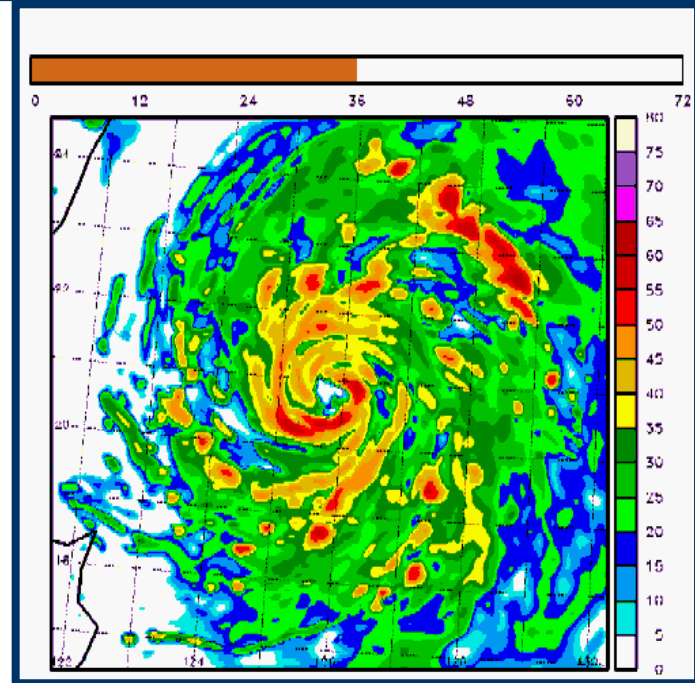
Prediction of Jangmi

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0000 UTC 26 September 2008 (72-h forecast)



Animation of COAMPS predicted radar reflectivity every 30 minutes on 5 km moving grid



COAMPS Forecast Track (red) and Official Warning Positions (black) plotted every 12 hours (dots)

- COAMPS-TC forecasted rapid intensification of Super Typhoon Jangmi, however the system stronger than observed by 72 h since the predicted TC did not make landfall.
- Convection was spotty and disorganized early in forecasts (esp. cold starts).
- Basic intensity metrics were encouraging for the first 36-48h of

09



COAMPS-TC

Improvements Following T-PARC/TCS08

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Azimuthally average tangential (shaded) and radial (contour) winds

Hurricane Katrina (72 h valid 00Z Aug 29, 2005, $\Delta x = 3\text{ km}$)

Physics Tests

• **TCS08 Version**

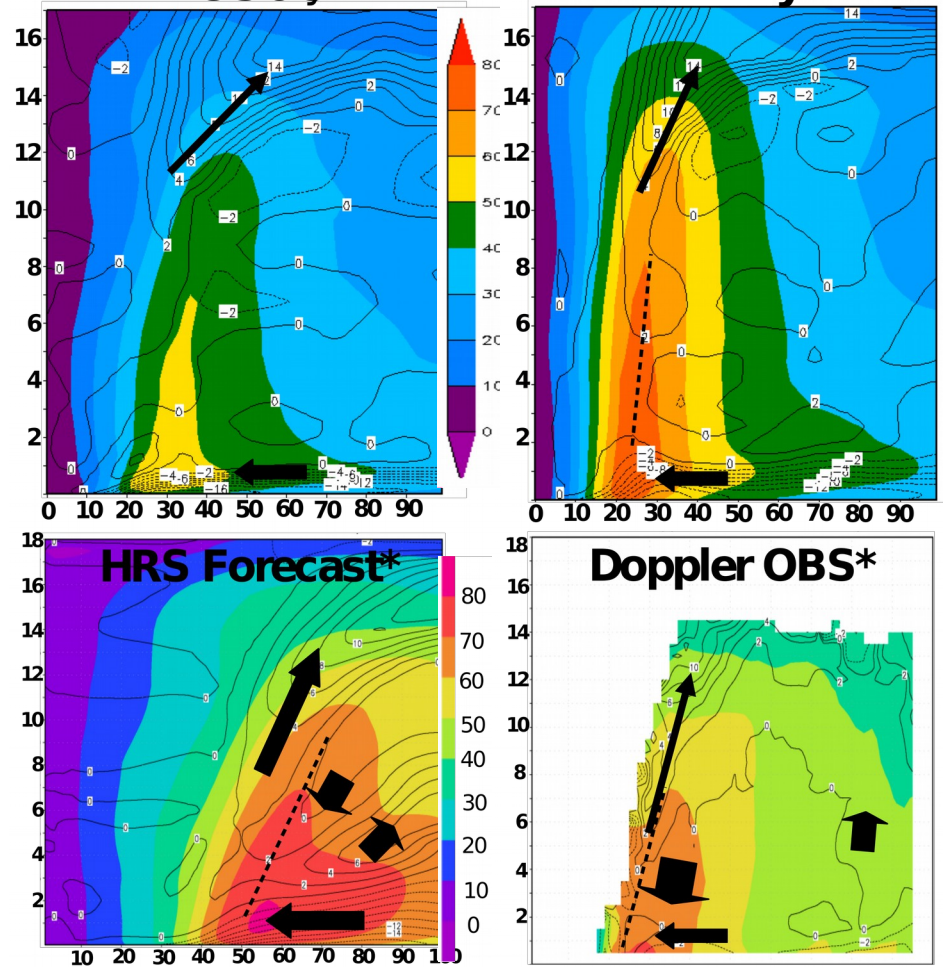
- No sea spray

• **New Physics**

- Bougeault type of mixing (PBL & above)
- New sfc moisture transfer coefficient
- New ice nucleation
- New dissipative heating formulation

• **New Physics Version**

- Improves the intensity forecasts
- Less tendency to overdevelop
- Improves the convective structure
- Good agreement with Doppler obs.





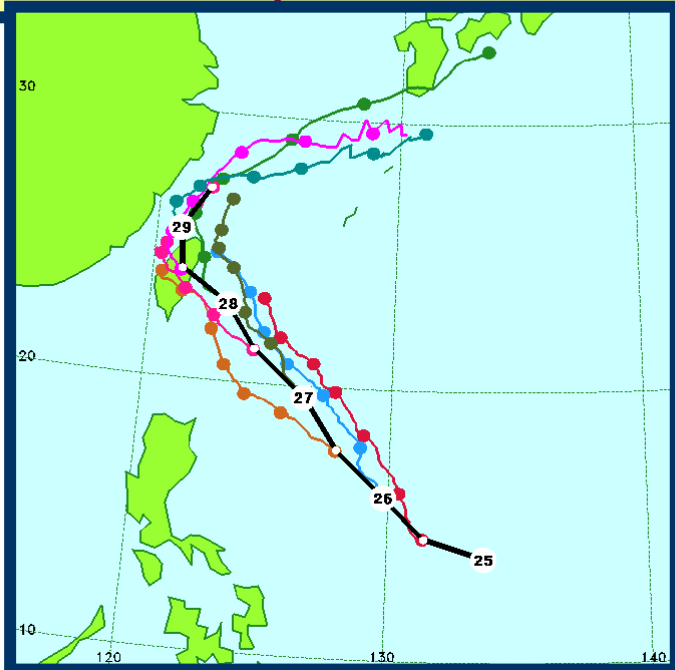
COAMPS-TC

Prototype Coupled Model Tests

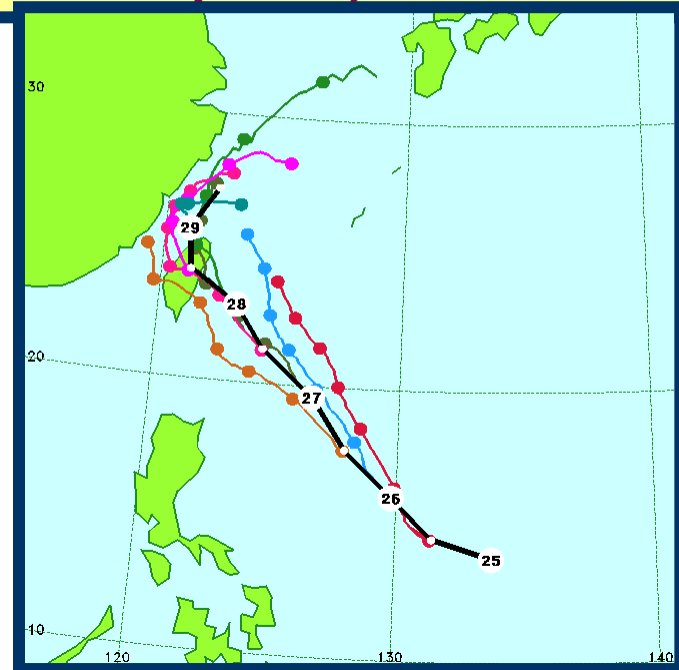
12

COAMPS-TC Air-Ocean Coupled Prediction of Typhoon Jangmi
Initial Time: 0000 UTC 2 September 2008

- COAMPS-TC and 2-way coupled model (COAMPS-NCOM-TC) run for TC 19W
- Significant differences between COAMPS-TC and COAMPS-NCOM: **NAVDAS vs. MVOI, 3-nest vs. 2-nest, Different synthetic observations, runs made on different computers, . . .**



COAMPS-TC



COAMPS-NCOM



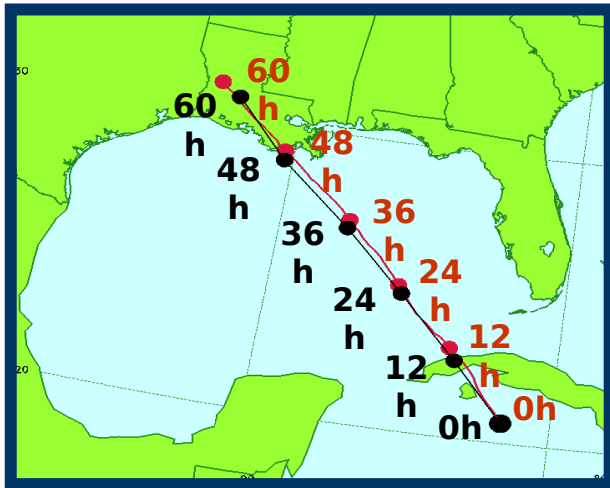
COAMPS-TC

Prototype Coupled Model Tests

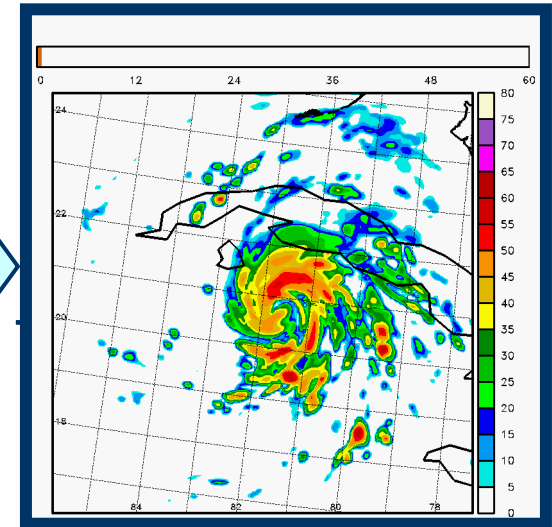
13

COAMPS-TC Air-Ocean Coupled Prediction of Hurricane Gustav

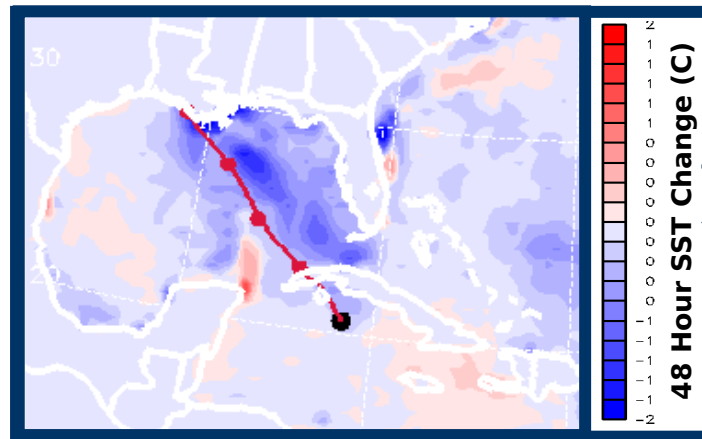
Initial Time: 1200 UTC 30 August 2008



**Animation of
COAMPS
predicted radar
reflectivity
every 30
minutes on 5 km
moving grid**



**COAMPS Forecast
Track (red) and
Official Warning
Positions (black)
plotted every 12
hours (dots) in
uncoupled run**



**SST cooling of
approximately
1°C-2°C is found
to the right of
the predicted
path of
Hurricane Gustav
(Initial position
is black dot, red
dots represent
every 12 hours)**



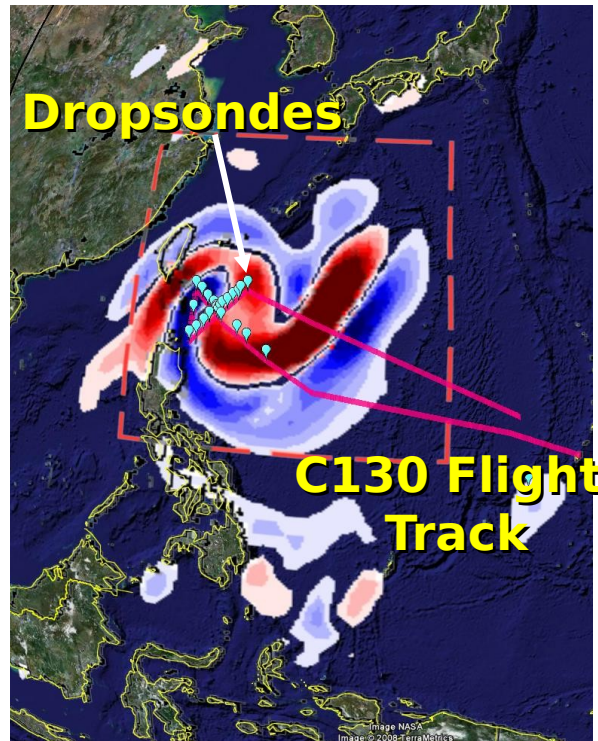
COAMPS-TC

Adjoint Targeted Observations (T-PARC/TCS08)

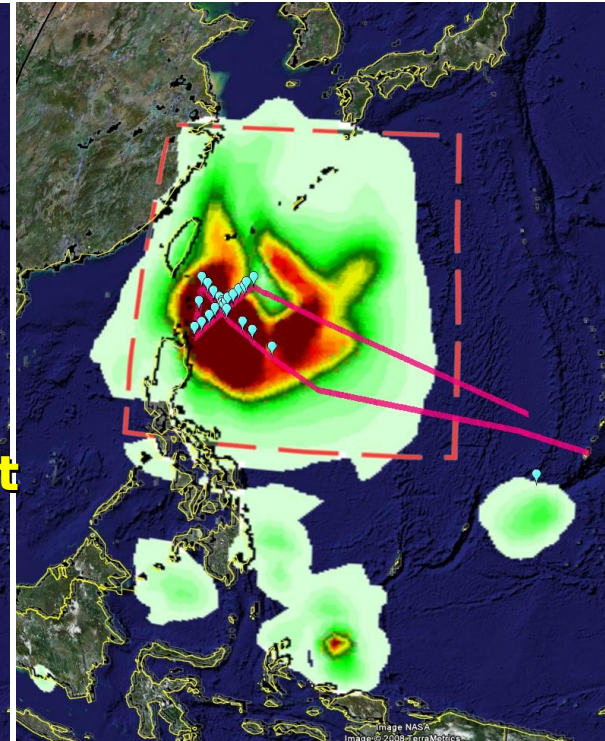
14

24-h adjoint sensitivity (36-h lead time)
Typhoon Sinlaku (Valid at 12Z 10 Sep 2008)

- Real-time COAMPS adjoint for targeting guidance.
- 40 km resolution for 24-h, 36-h, 48-h lead times.
- Adaptive response function box.



2-km vorticity
sensitivity



Total energy
sensitivity

- Vorticity sensitivity bands often anticyclonically curved.
- Strongest sensitivity to low- and mid-level θ and q_v .
- C130 often sampled key portions of the



COAMPS-TC

Conclusions and Future Research

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- COAMPS-TC Real-Time Runs for T-PARC/TCS-08:
 - **45/15/5 km nested grids**
 - **Promising forecasts of intensity and structure in a number of cases**
 - **Track forecast competitive with other models**
 - **Tendency to over-deepen TCs**
 - **Identified inconsistencies, bugs, oversights, . . .**
 - **Prototype air-ocean coupling tested on limited number of cases**
 - **Adjoint sensitivity calculations used for target observations**
- Future Research:
 - **Improve initial mass/wind balance, analysis (recent improvements)**
 - **Improve handling of convection in 3-5 km regime (recent breakthrough?)**
 - **Test air-ocean and air-ocean-wave coupling**
 - **Community interactions with HFIP, ONR/NOAA NOPP, ONR ITOP**
 - **Real-time demo in 2009 with FNMOC, Coordination with HFIP**



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Prototype Coupled Model Tests

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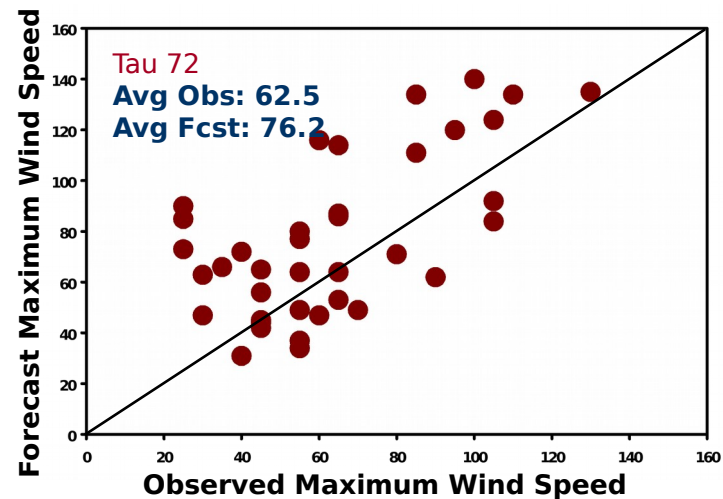
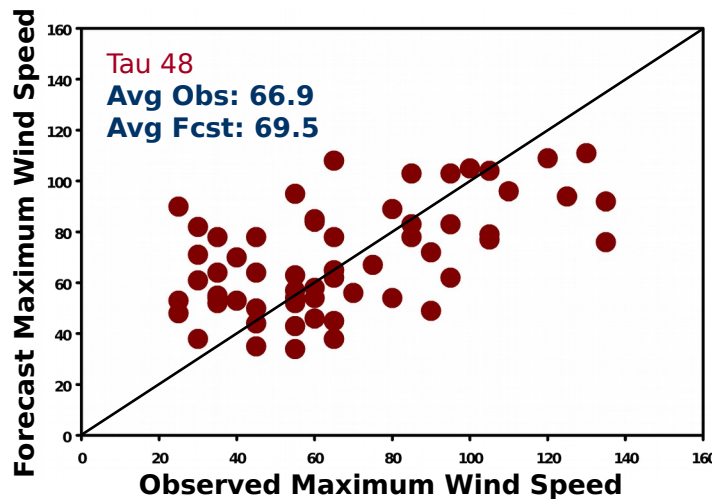
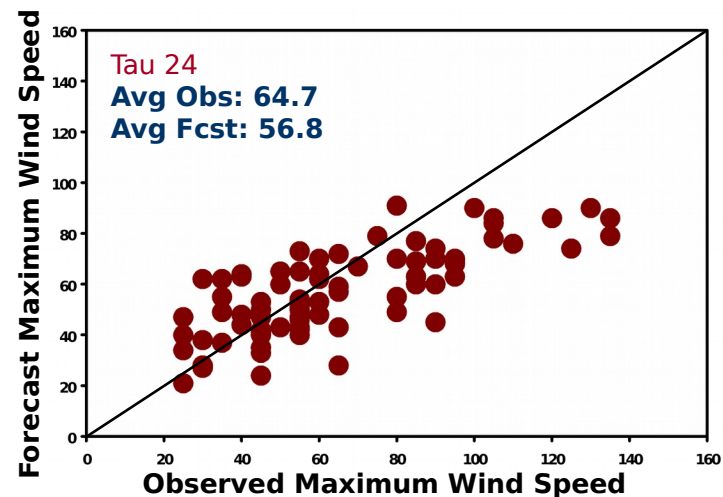
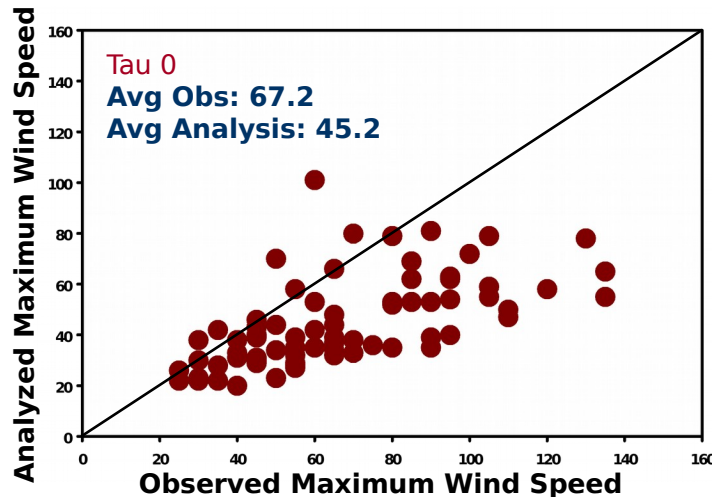
- Run in Real-Time during latter phase of TCS-08
- COAMPS-NCOM Coupled with ESMF
- Atmosphere:
 - **45/15 km nested grids (181x151, 121x121; 40L)**
 - **45 km grid same as in coamps real-time uncoupled runs**
 - **15 km grid moves w/TC**
 - **15 km grid position set by warning position**
 - **MVOI used for analysis**
- Ocean:
 - **Global NCOM fields used for lateral boundary conditions**
 - **45 km grid (151x121; 37L)**
 - **Warm starts after initial cold start (using global NCOM)**
- Coupling Frequency: 30 minutes



Observed vs. COAMPS-TC Maximum Wind Speed

Wind Speeds in knots

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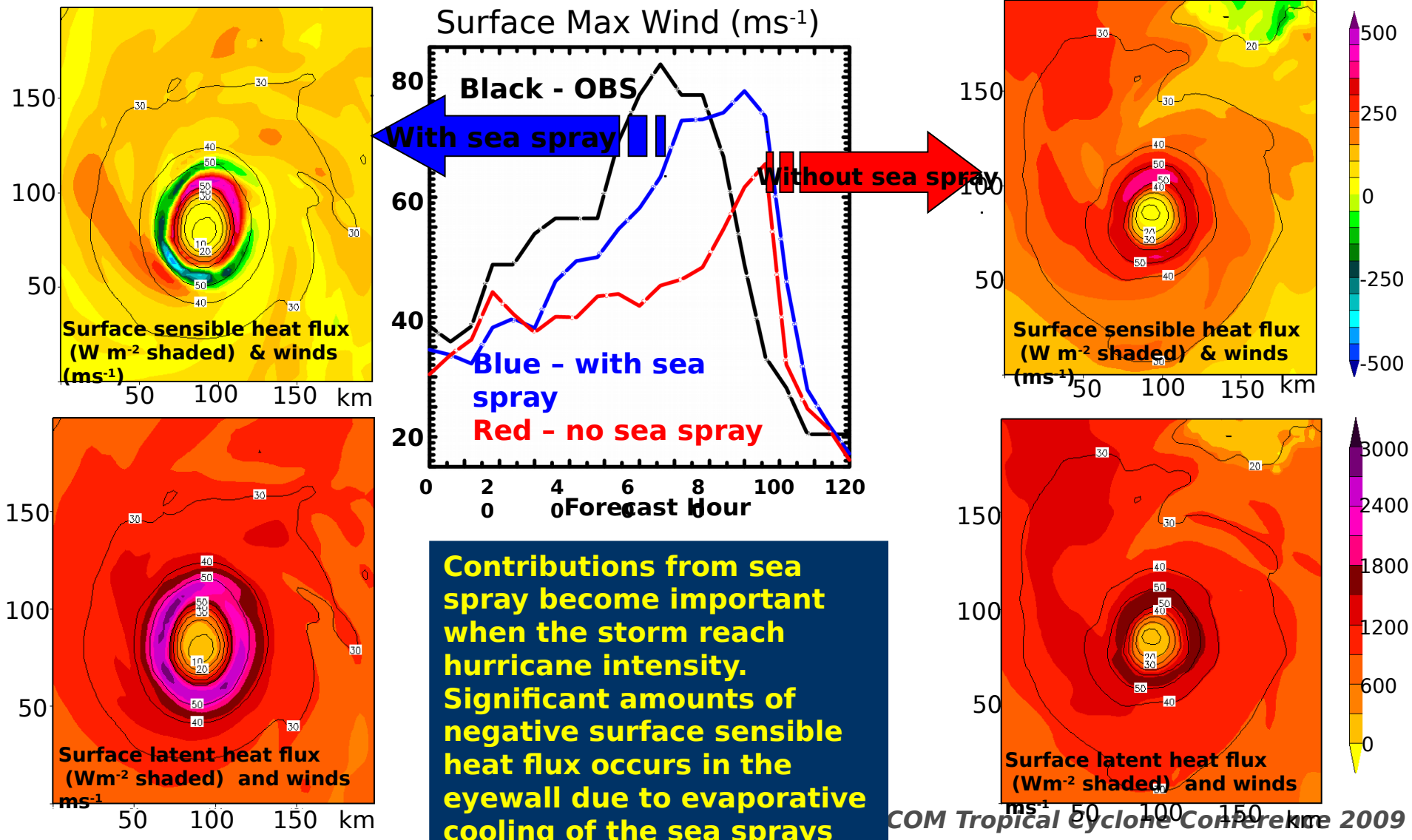
Results show that COAMPS-TC underestimates TC max wind speed at analysis time, but tends to increase TC max winds relative to the analyzed wind speeds with forecast time



Sea Spray Parameterization

Hurricane Katrina (26-31 Aug 2005, 3-km)

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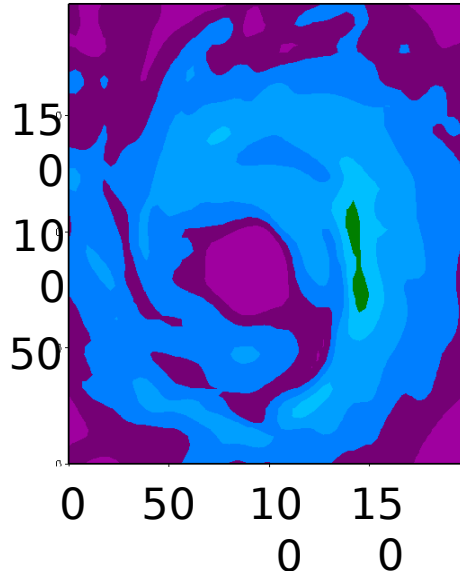
COAMPS - TC

Parameterization Evaluation

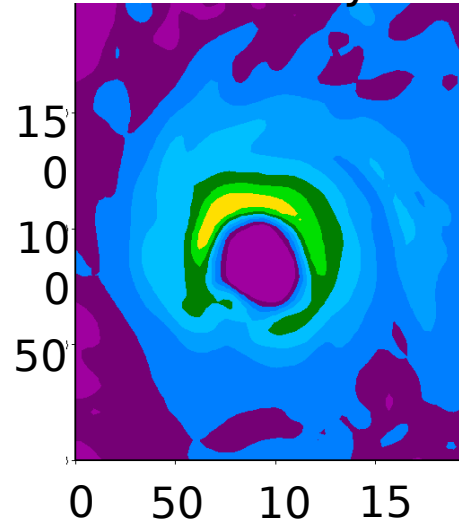
20

Vortex-scale fields – winds at 2 km altitude
(72 h forecast valid at 00 Z Aug 29 2005, 3-km)

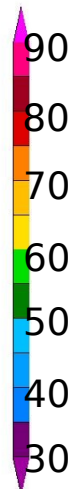
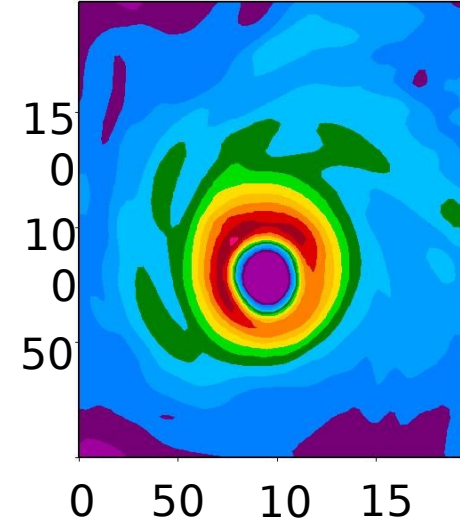
Bench



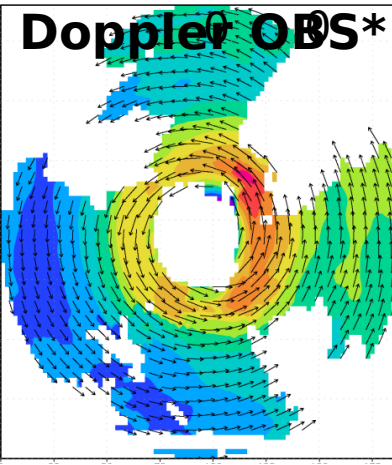
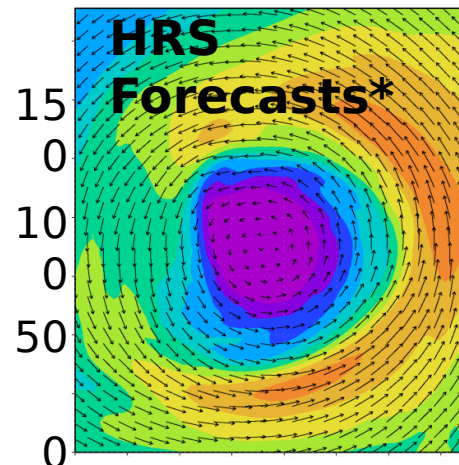
NewPhys



Mix



- New mixing length run simulates most realistic intensity & structure
- Bench version did not intensify the Katrina



The Doppler Observations and the HRS forecasts are provided by R. Rogers of HRD.

USPACOM Tropical Cyclone Conference 2009

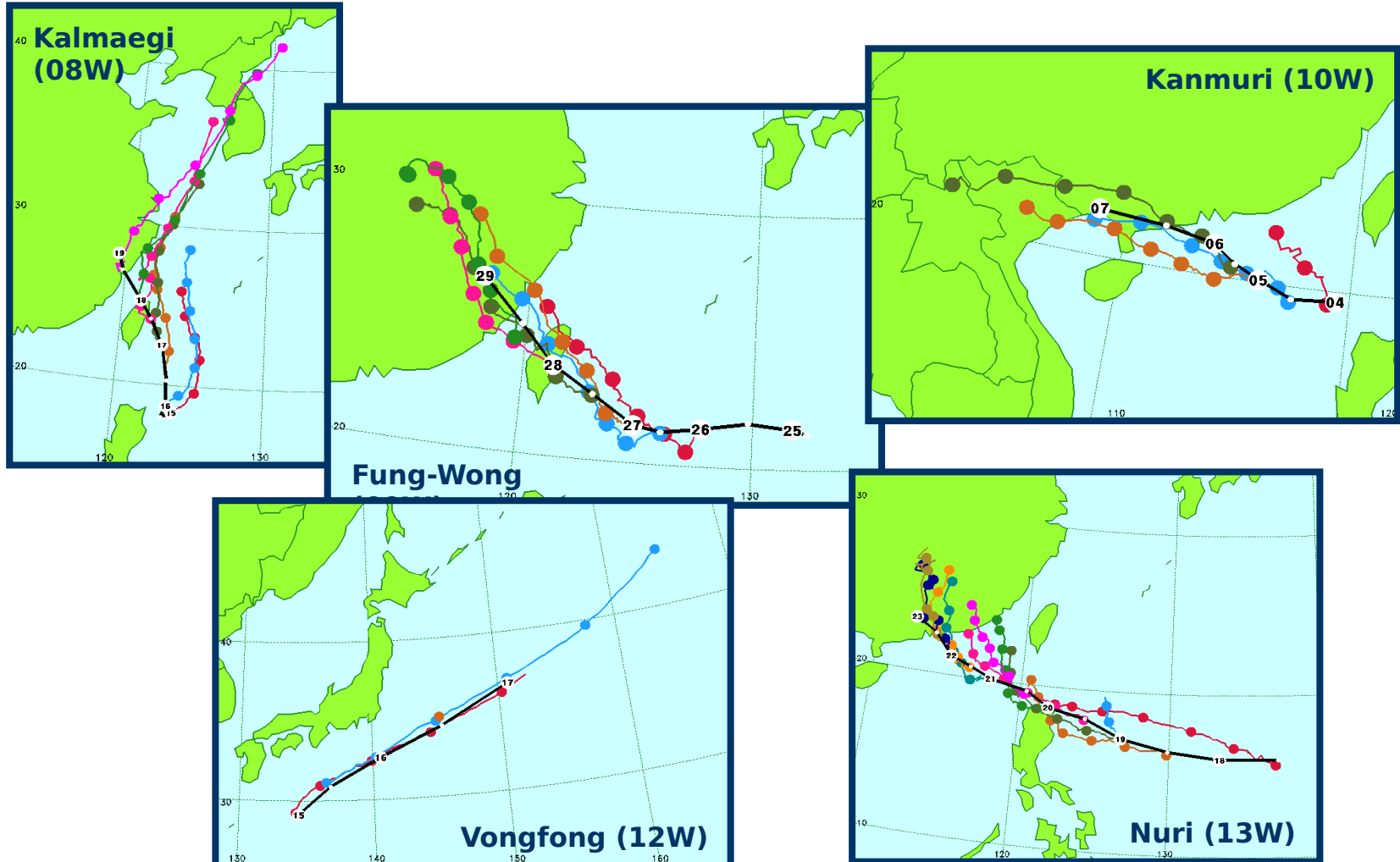


COAMPS-TC Track Forecasts of Named Storms During TCS-08

21

Black line: **Warning positions, large white circle with day at 0000 UTC, small white circle at 1200 UTC.**

Colored lines: **COAMPS forecasts starting from different times with a circle every 12 hours.**



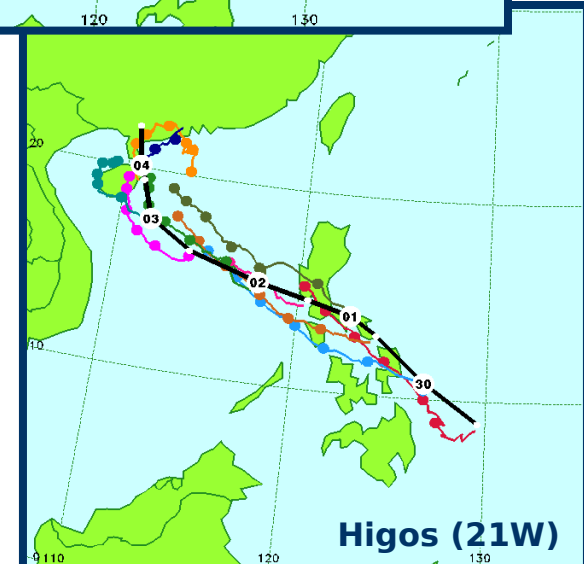
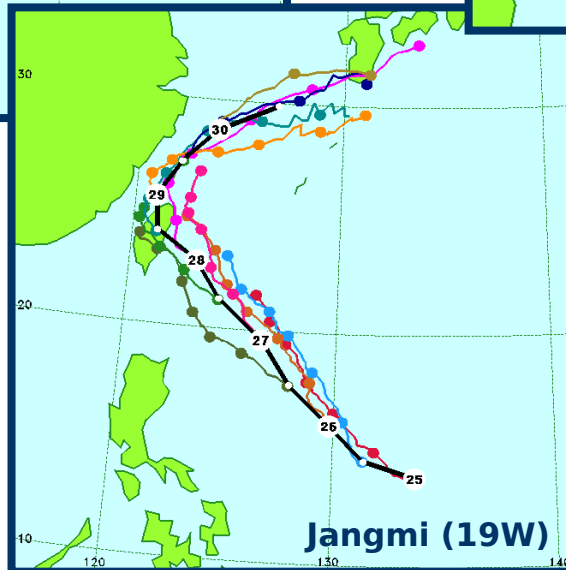
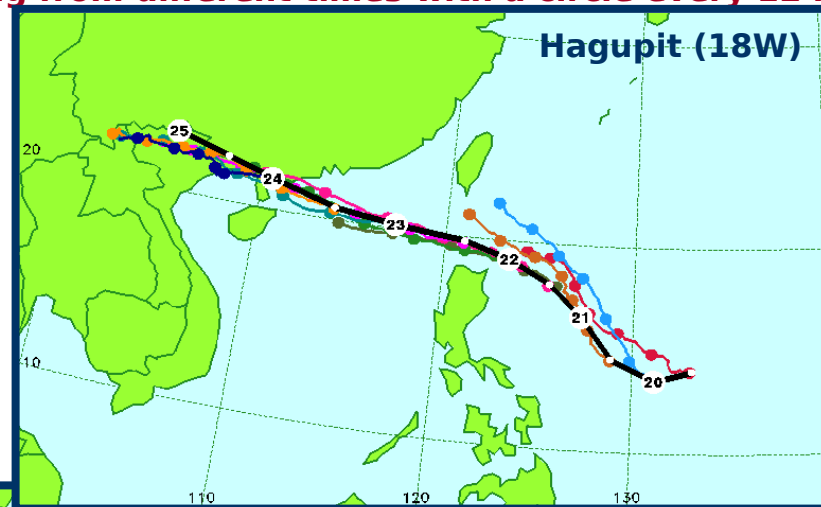
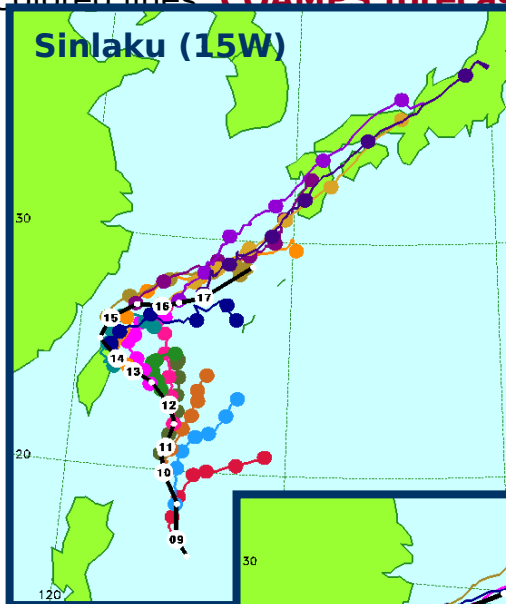


COAMPS-TC Track Forecasts of Named Storms During TCS-08

22

Black line: **Warning positions**, large white circle with day at 0000 UTC, small white circle at 1200 UTC.

Colored lines: **COAMPS forecasts** starting from different times with a circle every 12 hours.

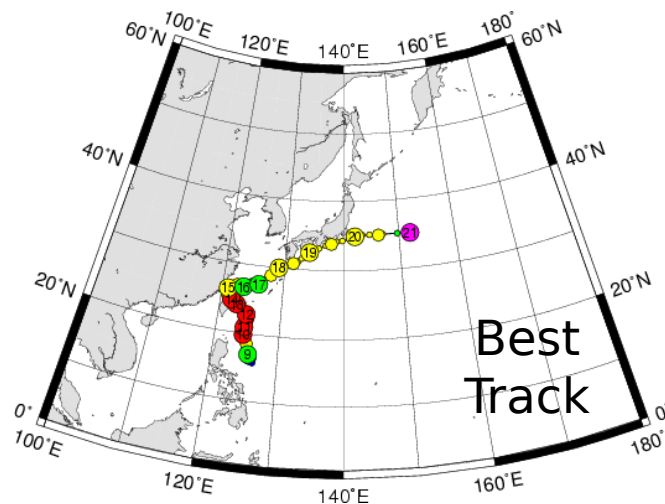




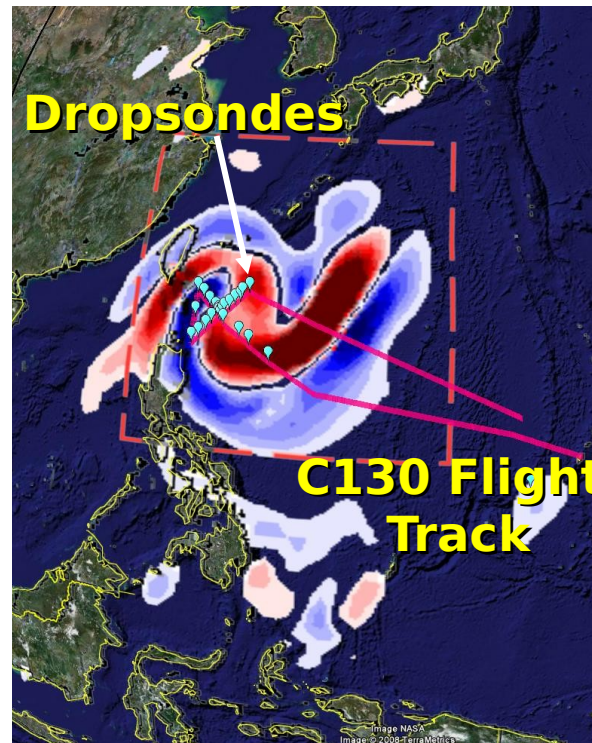
TPARC/TCS08 Real-Time Adjoint Forecasts

TC Sinlaku

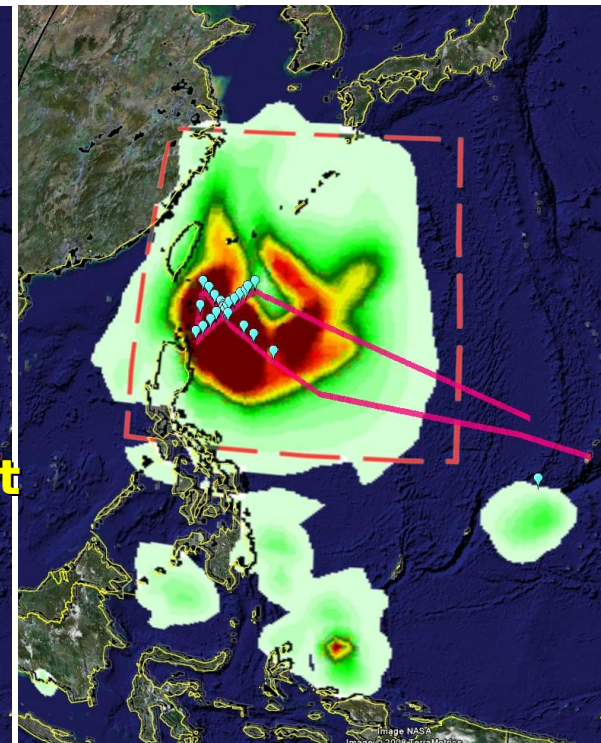
23



**24-h adjoint sensitivity
36-h lead time
Valid at 12Z 10 Sep
2008**



**2-km vorticity
sensitivity**



**Total energy
sensitivity**

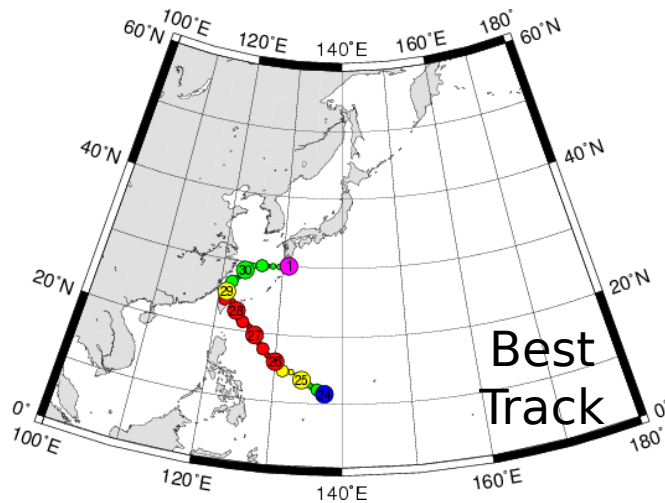
- Vorticity sensitivity bands that are anticyclonically curved.
- Strongest sensitivity to low- and mid-level θ and q_v .
- C130 sampled key portions of the sensitivity.



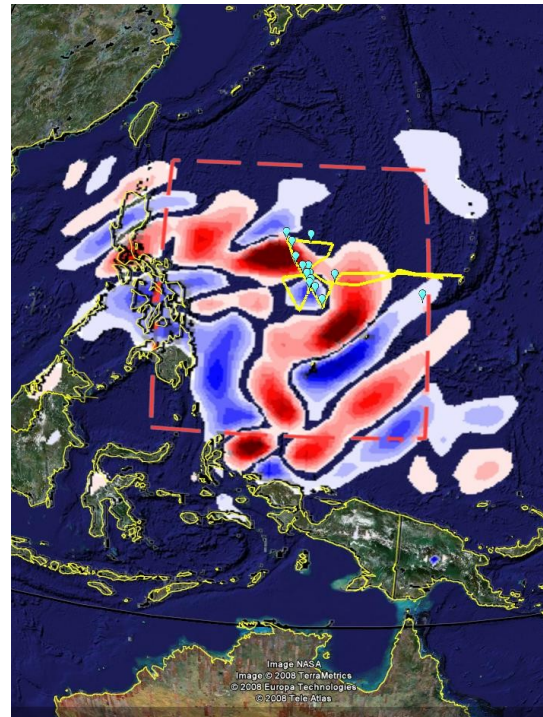
TPARC/TCS08 Real-Time Adjoint Forecasts

TC Jangmi

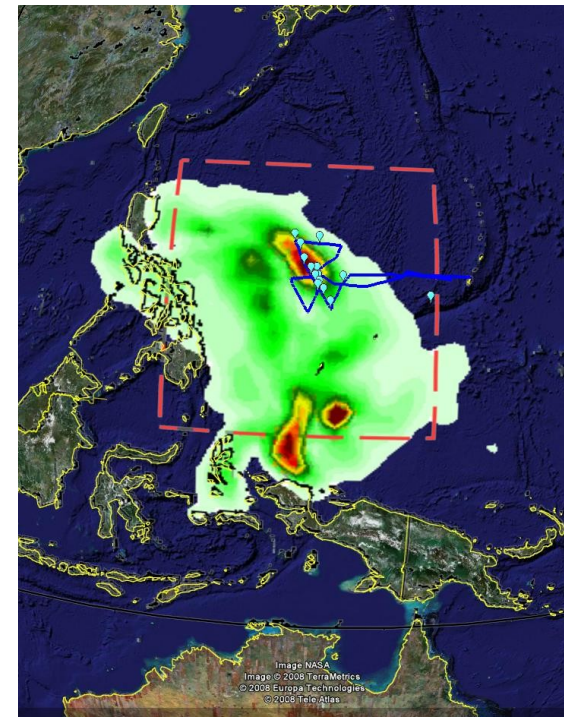
24



**24-h adjoint sensitivity
36-h lead time
Valid at 00Z 25 Sep
2008**



**2-km vorticity
sensitivity**



**Total energy
sensitivity**

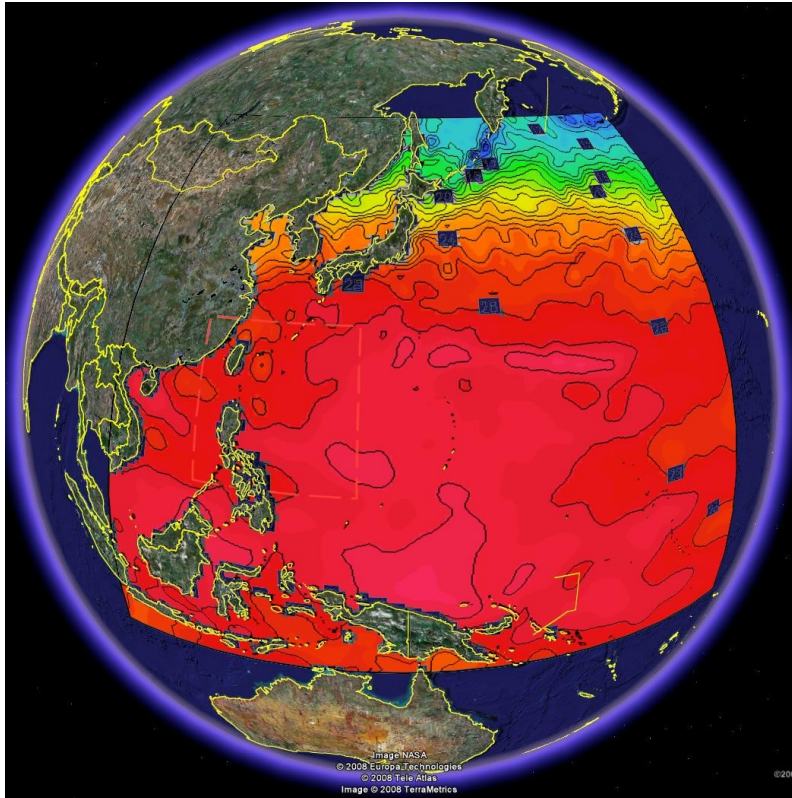
- Vorticity sensitivity shows a wave packet pattern.
- The θ and q_v sensitivity have multiple maxima over a broad area.
- C130 sampled only a small portion of the sensitivity.



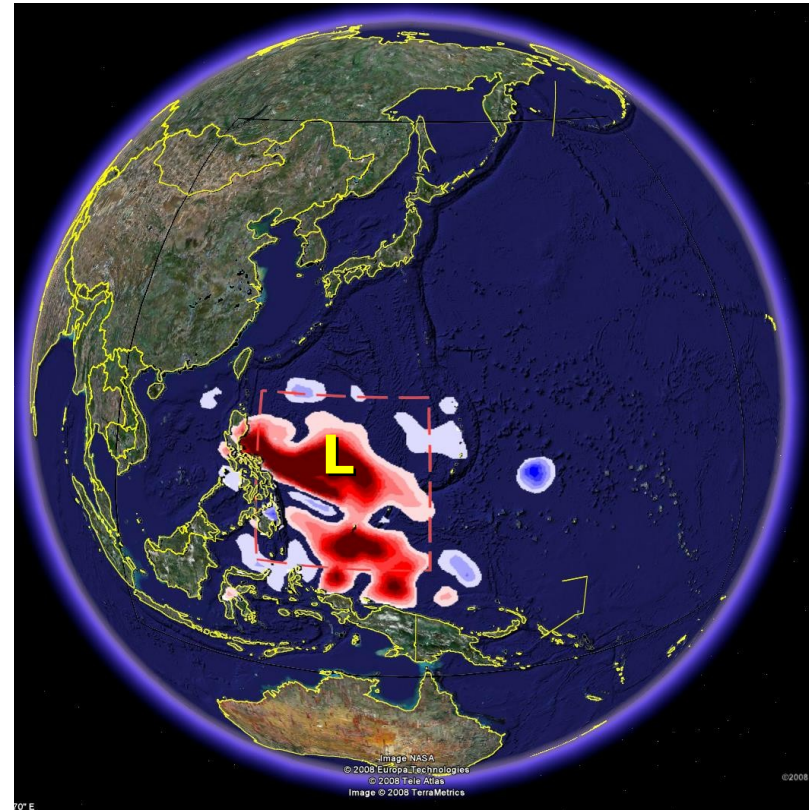
TPARC/TCS08 Real-Time Adjoint Forecasts

TC Jangmi

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**SST Valid at 00Z 25 Sep
2008**



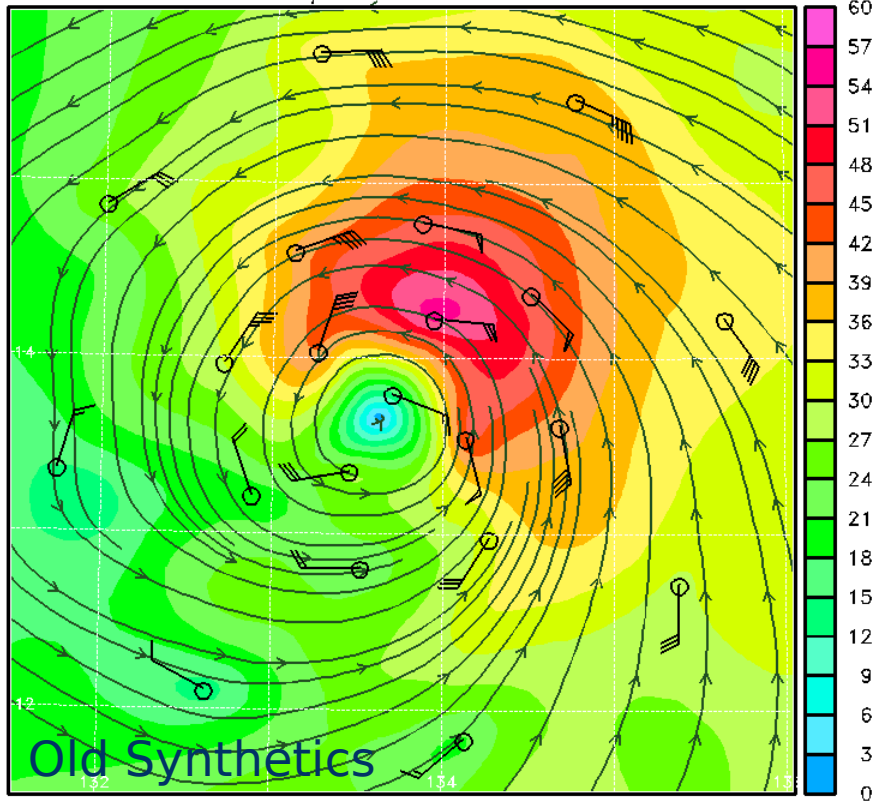
**Surface temperature (SST)
sensitivity**

- SST sensitivities were computed in real time.
- The SST sensitivity often showed complex patterns.
- G130 deployed many AYRTs during T

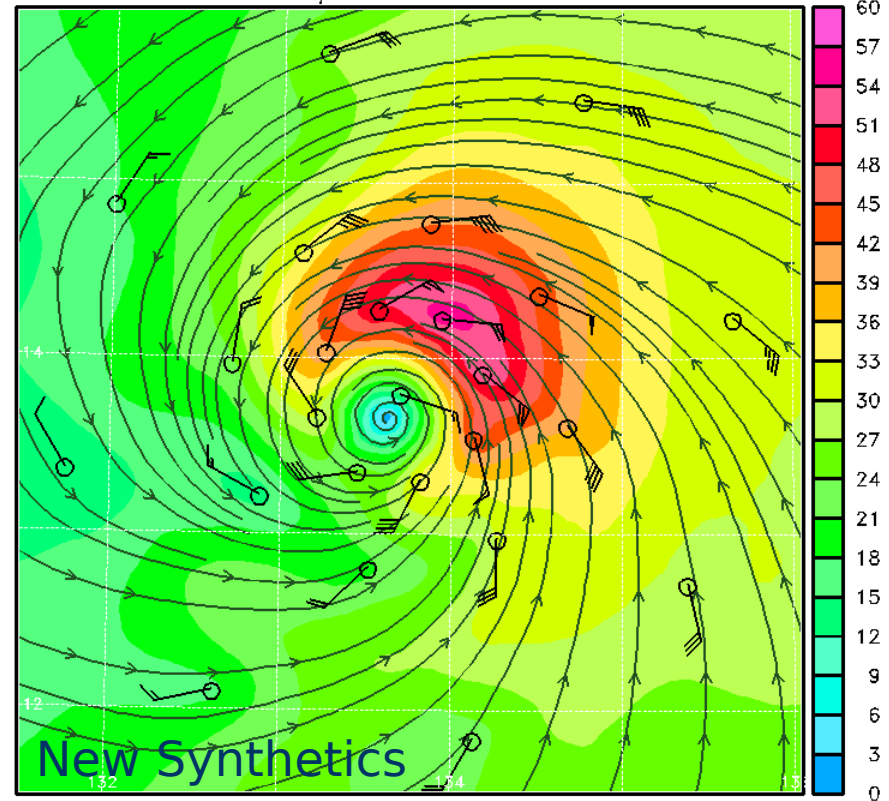
Comparison of Analyses of TC Jangmi using Old Synthetics and New Synthetics at 1000 mb

Analysis Time: 2008092500

COAMPS grid 3, 181 x 181 x 40 5.00 km
1000.0 mb wind field
analysis at 2008092500
TC 1000.0 mb geop ht and wind
analysis at 2008092500



COAMPS grid 3, 181 x 181 x 40 5.00 km
1000.0 mb wind field
analysis at 2008092500
TC 1000.0 mb geop ht and wind
analysis at 2008092500



Comparison of Analyses of TC Jangmi using Old Synthetics and New Synthetics at 700 mb

Analysis Time: 2008092500

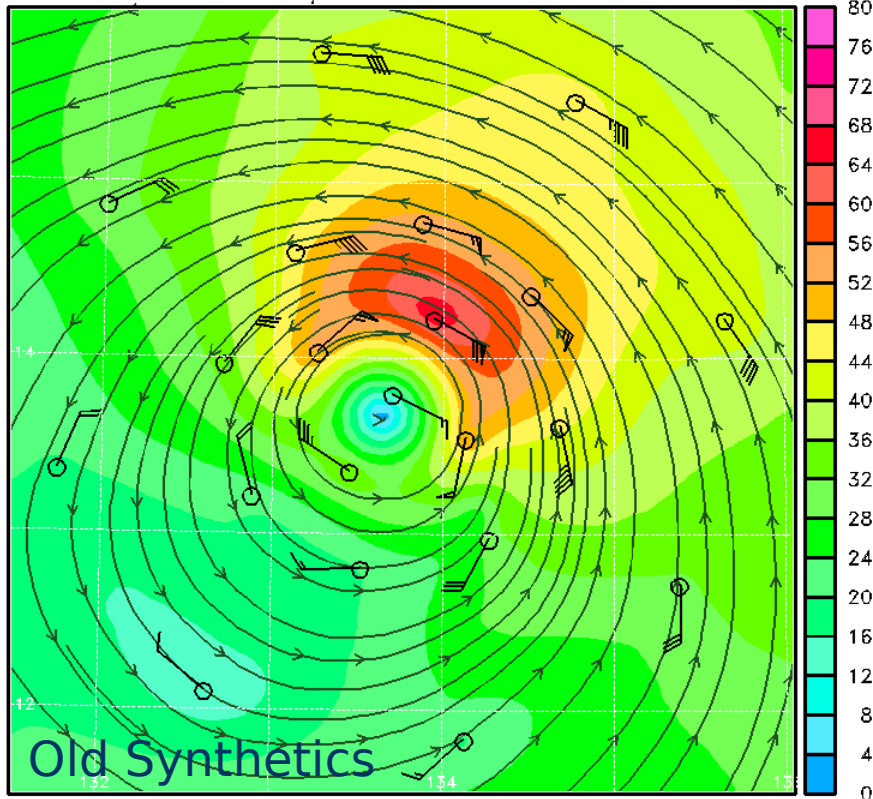
COAMPS grid 3, 181 x 181 x 40 5.00 km

700.0 mb wind field

analysis at 2008092500

TC 700.0 mb geop ht and wind

analysis at 2008092500



COAMPS grid 3, 181 x 181 x 40 5.00 km

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